LOW THRUST PROPULSION

INTEGRATED TECHNOLOGY PLAN

EXTERNAL REVIEW

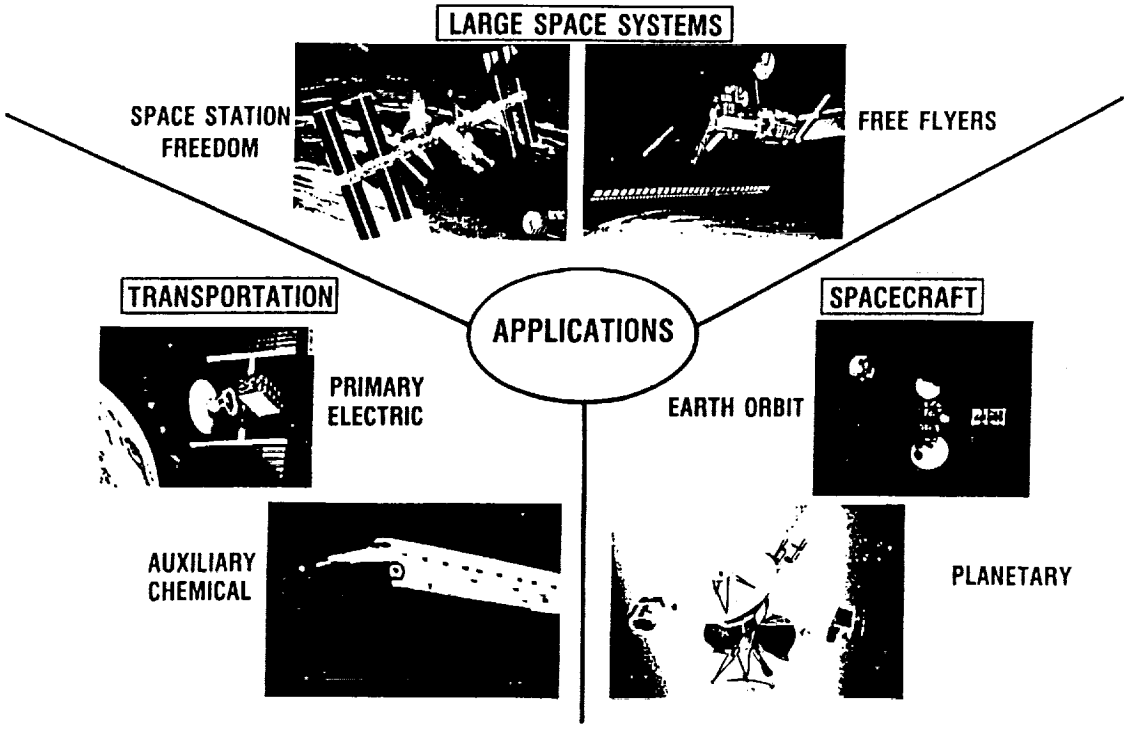
JUNE 26, 1991

LOW THRUST PROPULSION

AGENDA

- APPLICATIONS
- OBJECTIVE
- STATE-OF-ART MISSION IMPACTS
  - EARTH SPACE
  - PLANETARY
- PROGRAM
  - APPROACH
  - CONTENT
    - = "STRATEGIC"
    - = "CURRENT"
- ADVANCED TECHNOLOGY BENEFITS
- SUMMARY

LOW THRUST PROPULSION



LOW THRUST PROPULSION

OBJECTIVE

PROVIDE TECHNOLOGIES FOR A BROAD RANGE OF FUTURE SPACE SYSTEMS

- **SPACECRAFT**
  - **—PLANETARY**
  - **—EARTH-ORBITAL**
- **LARGE SPACE SYSTEMS**
  - **—SPACE STATION**
  - **—TENDED**
- **VEHICLES**
  - **—EARTH-TO-ORBIT**
  - **—ORBIT TRANSFER**

CD-90-47460

STATE-OF-ART

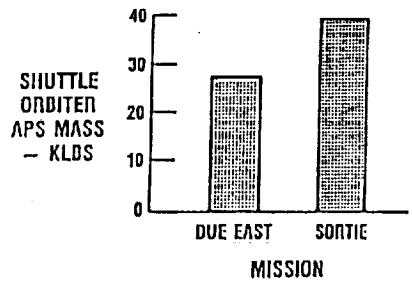
LOW THRUST PROPULSION

MISSION IMPACTS

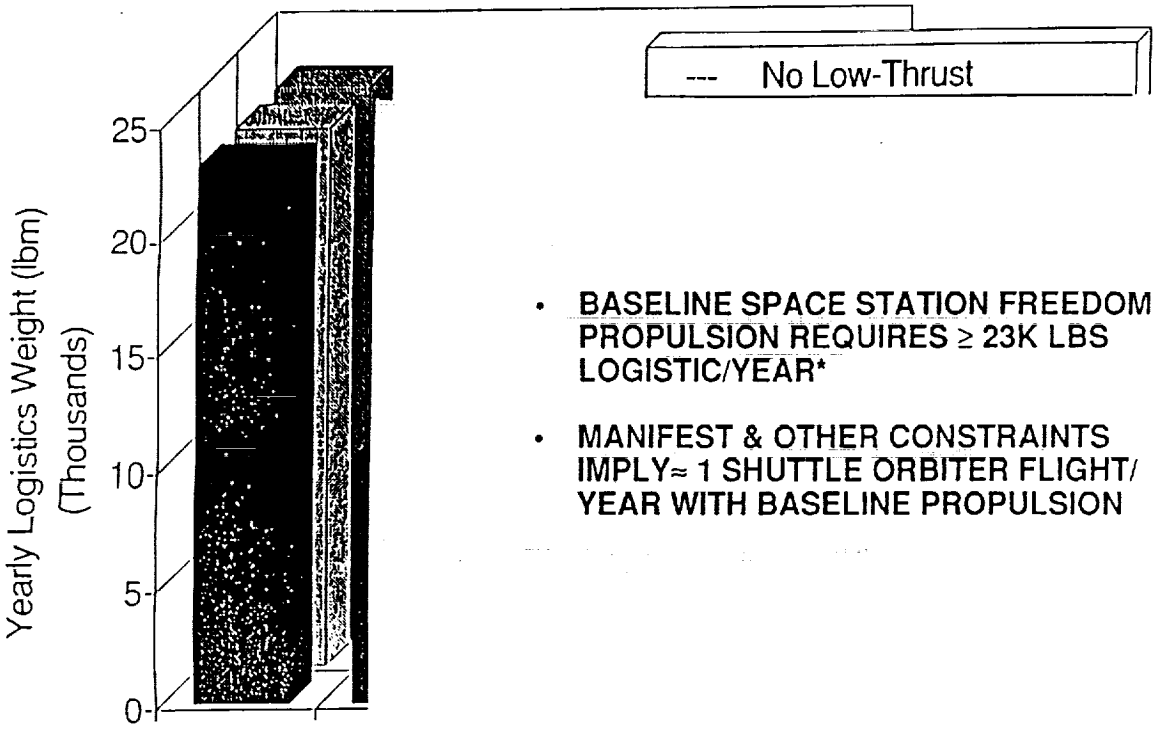
- LOW EARTH ORBIT (LEO):
  - ORBITER APS
  - SPACE STATION
- GEOSYNCHRONOUS (GEO):
  - TRANSFER ORBIT (GTO)
  - SATELLITES
- PLANETARY

LOW THRUST PRIMARY AND AUXILIARY PROPULSION

APS OFFERS MAJOR LEVERAGE



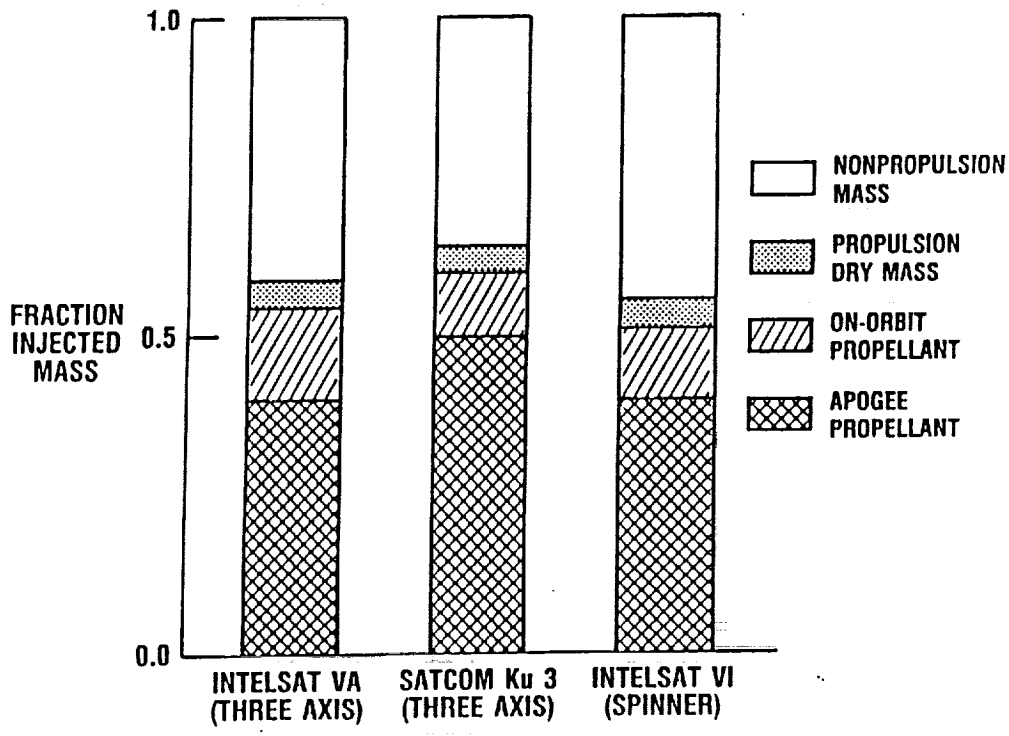
• APS MASS IS 11.4% TO 18.6% OF ORBITER



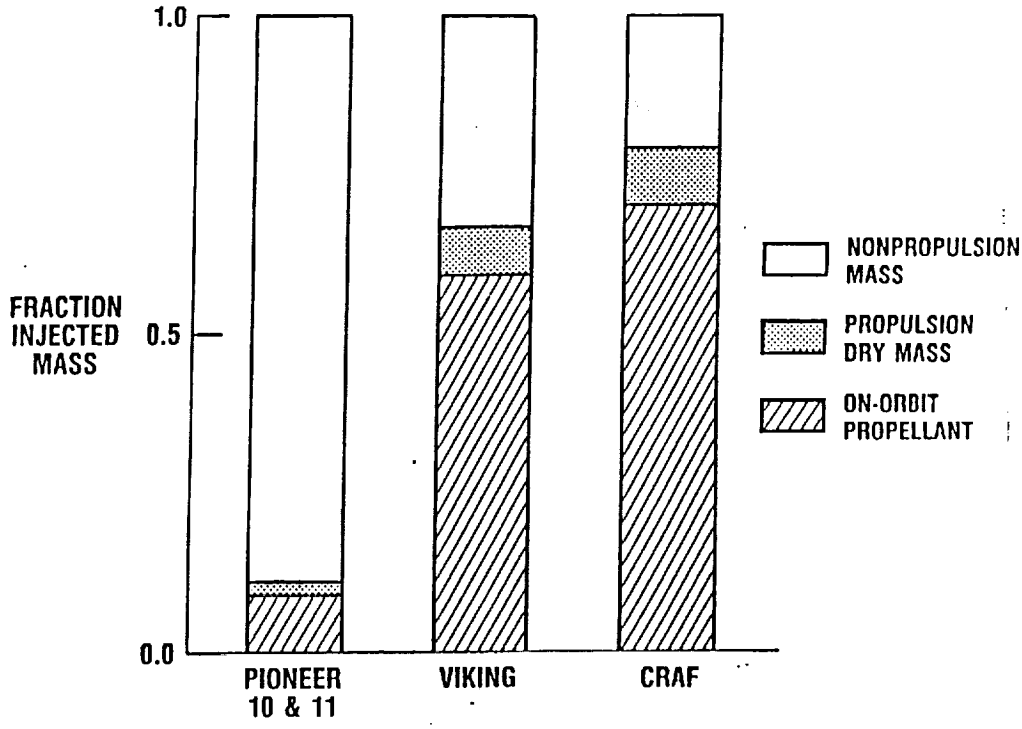
- BASELINE SPACE STATION FREEDOM PROPULSION REQUIRES ≥ 23K LBS LOGISTIC/YEAR*
- MANIFEST & OTHER CONSTRAINTS IMPLY≈ 1 SHUTTLE ORBITER FLIGHT/ YEAR WITH BASELINE PROPULSION

* AVERAGED OVER 11 YEAR CYCLE

GEOSYNCHRONOUS TRANSFER ORBIT MASS FRACTIONS FOR RECENT COMMUNICATIONS SATELLITES



PLANETARY SPACECRAFT INJECTED MASS FRACTIONS



STATE -OF-ART

LOW THRUST PROPULSION

MISSION IMPACTS

LEO

- 12-19% OF ORBITER DELVERED MASS (> 50% OF PAYLOAD)
- ~ ORBITER/YEAR FOR SPACE STATION LOGISTICS

GEO

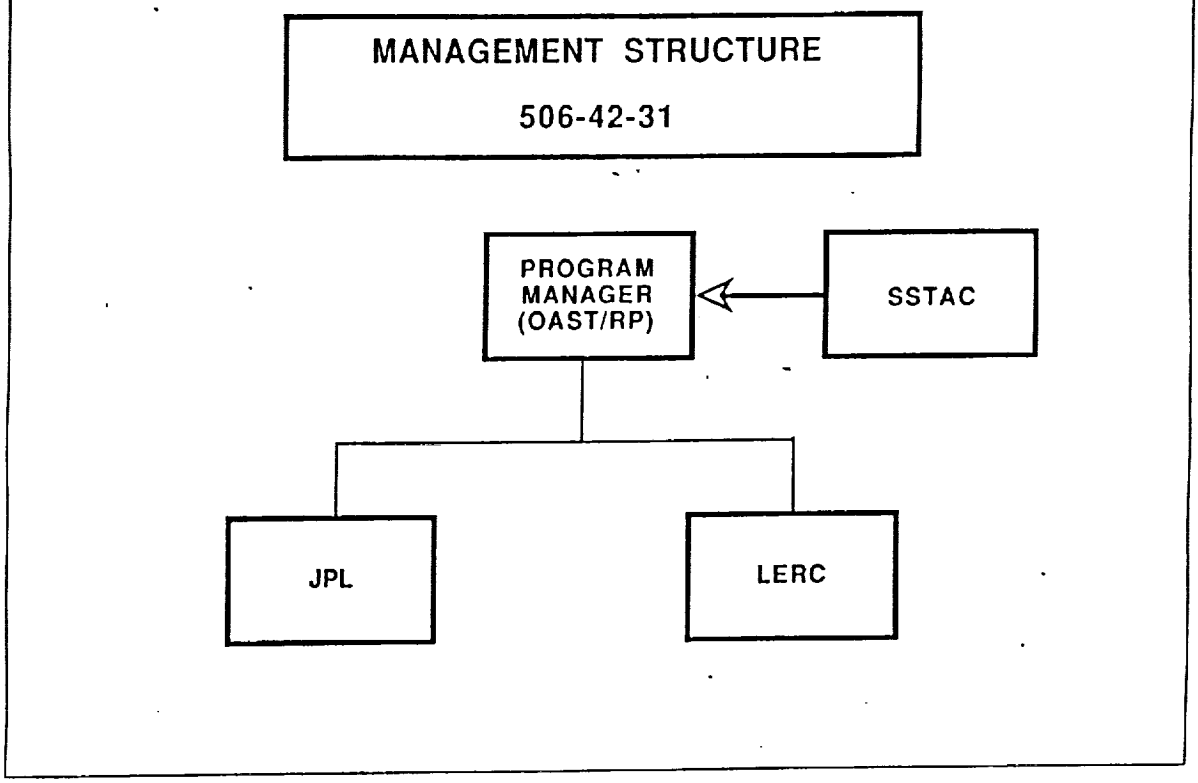
- 55-65% OF MASS DELIVERED TO GTO
- ON-ORBIT LIFE LIMITER

PLANETARY

- OVER 80% OF INJECTED MASS FOR PLANNED MMII MISSIONS

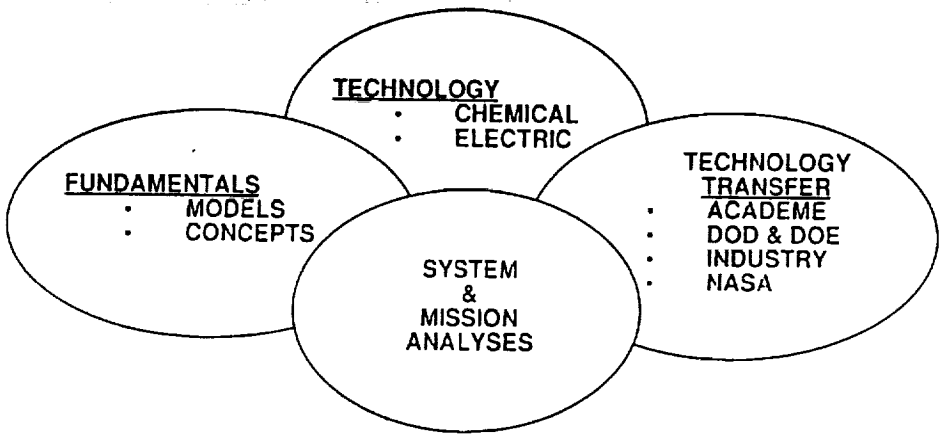
IN-SPACE FRACTIONAL MISSION PENALTIES REDUCED ONLY BY IMPROVED IN-SPACE PROPULSION

LOW THRUST PRIMARY & AUXILIARY PROPULSION



LOW THRUST PROPULSION

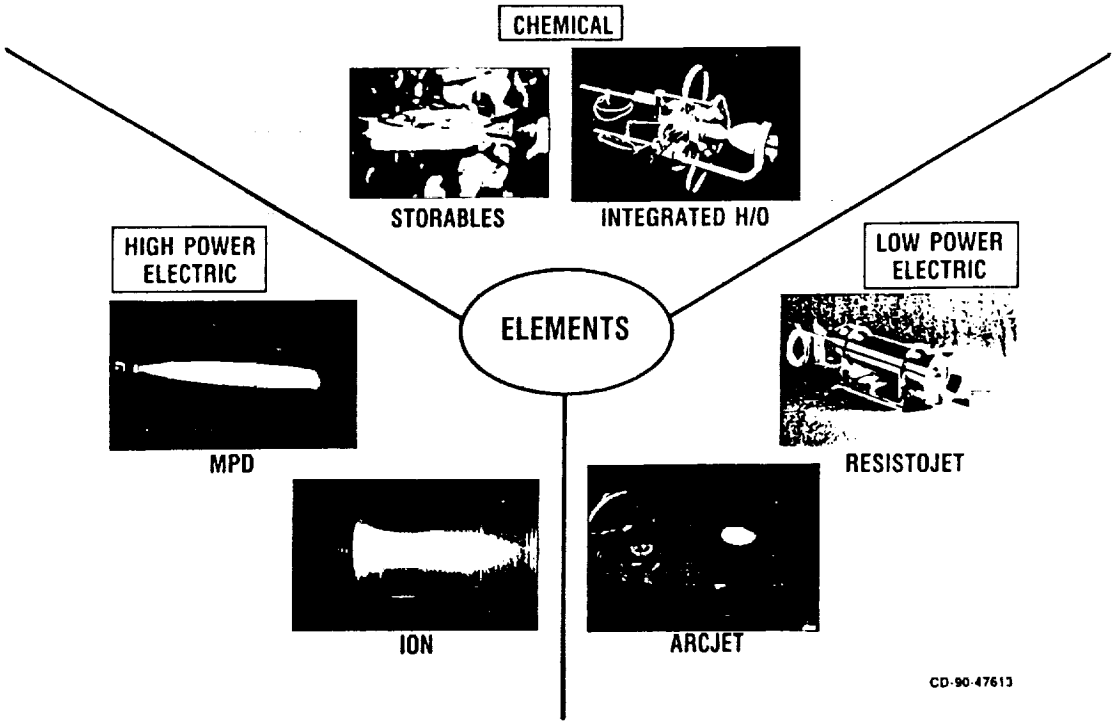
PROGRAMMATIC APPROACH



PROGRAM STRUCTURED TO SUPPORT:

- TECH TRANSFER & APPLICATIONS VERSUS TIME
- MAJOR BENEFITS FOR FUTURE MISSIONS

LOW THRUST PROPULSION



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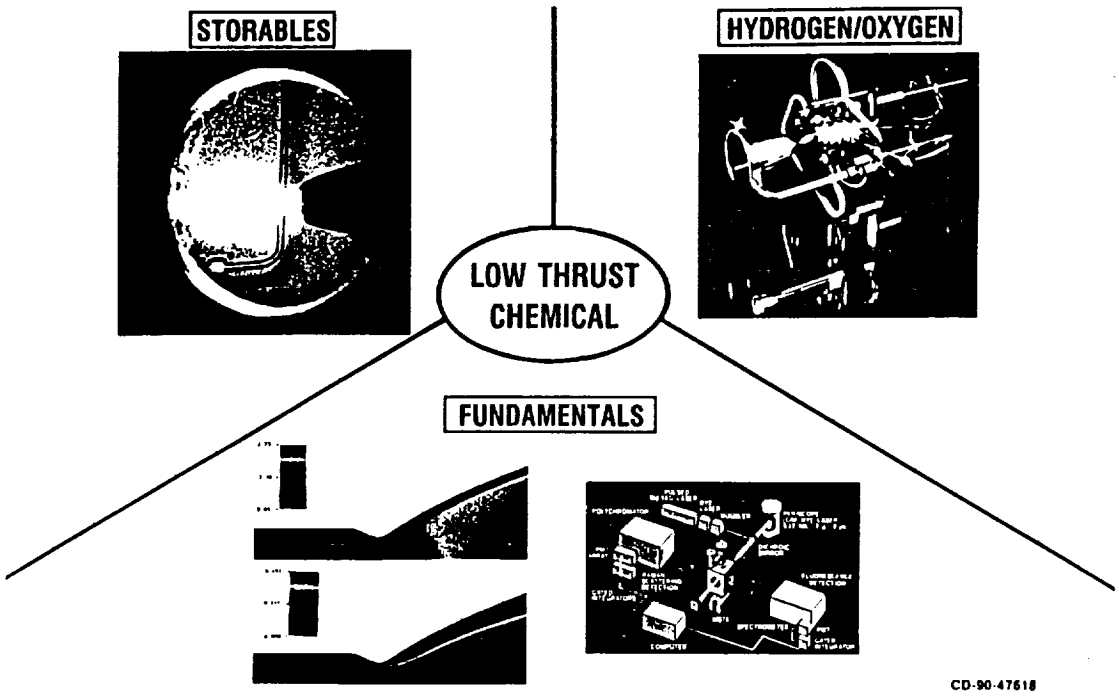

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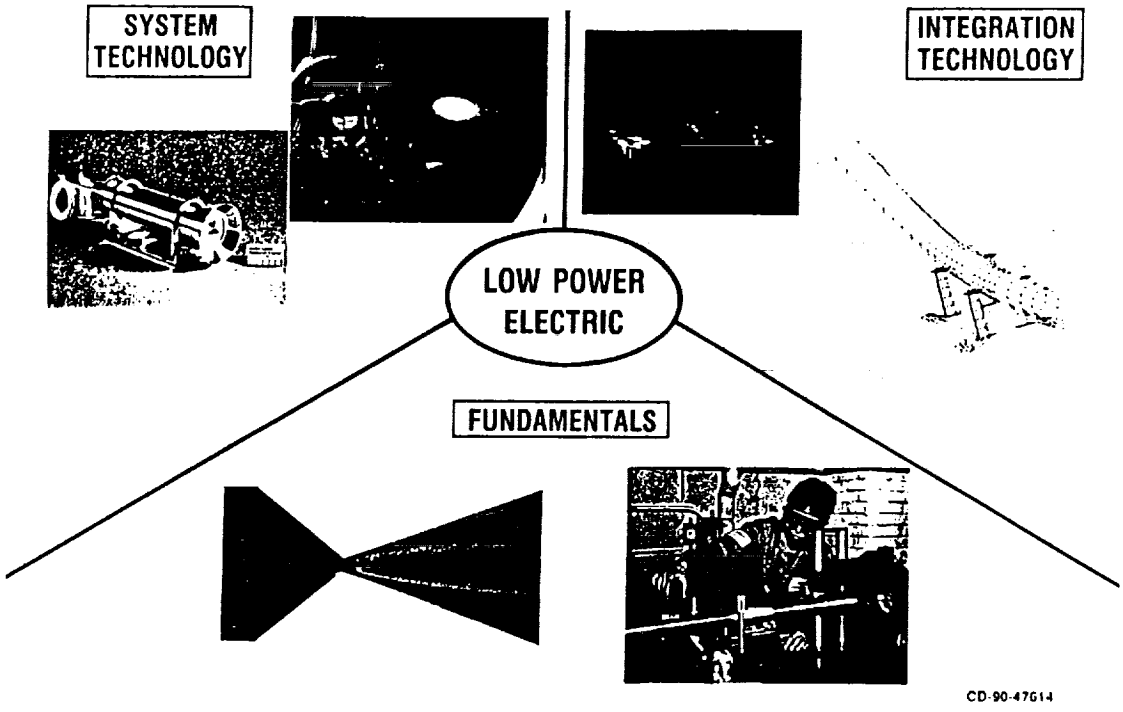
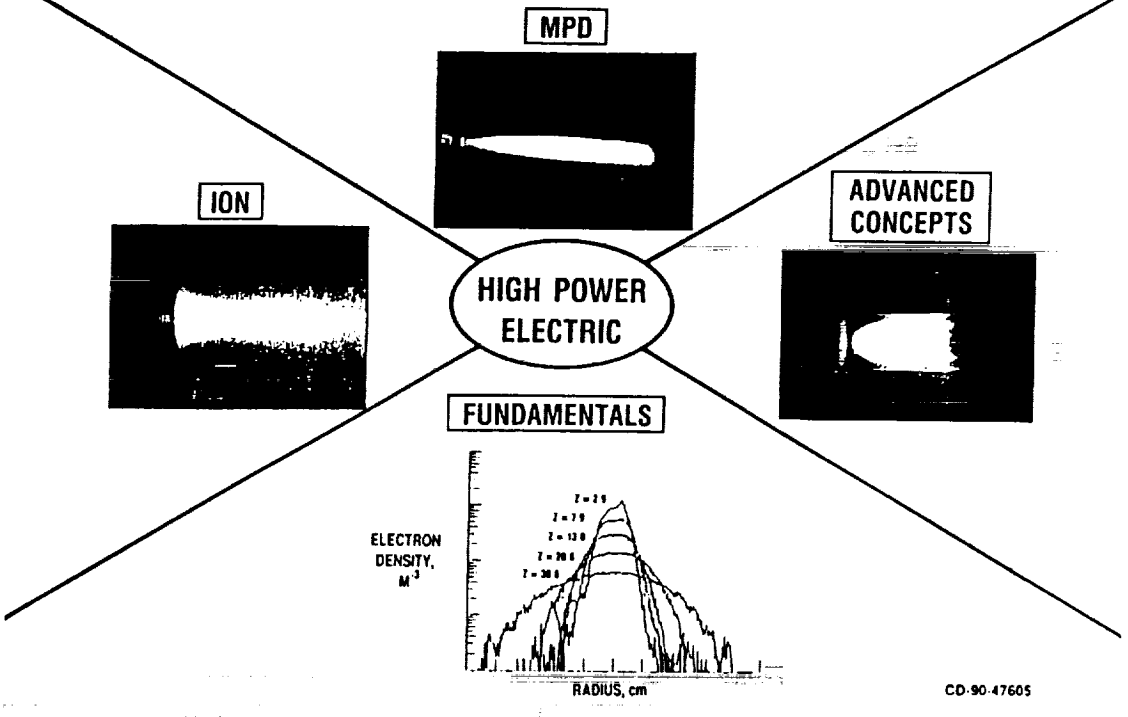


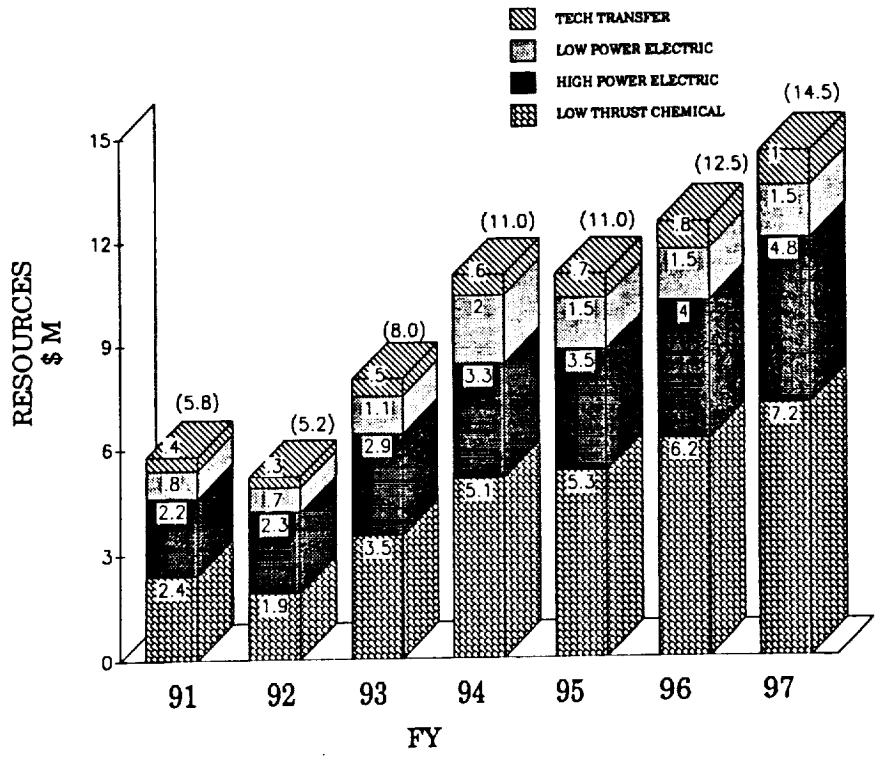
LOW THRUST PROPULSION



MECHANISMS/EFFORTS

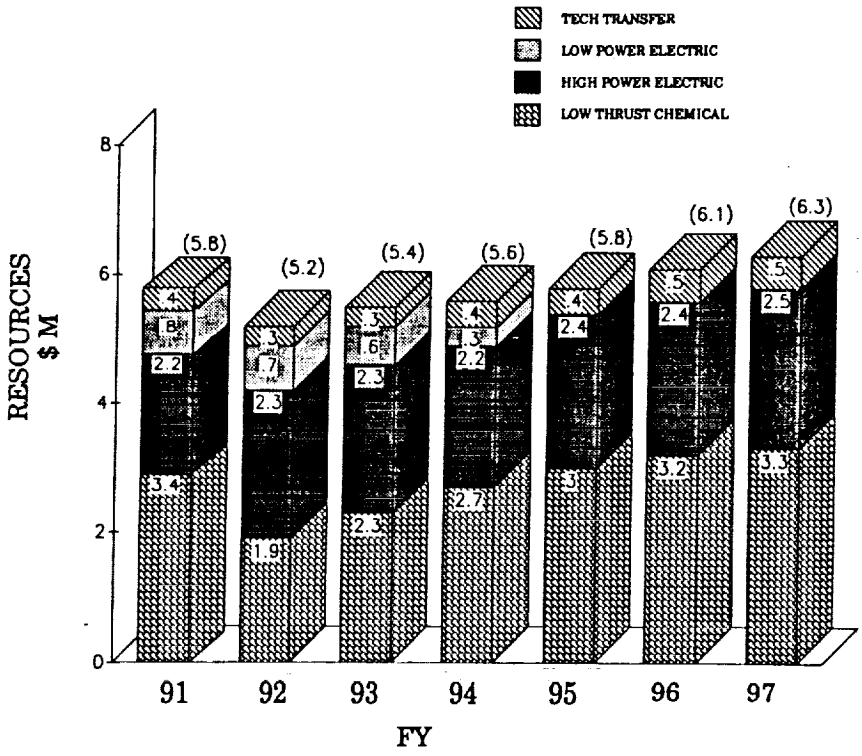
- SPACE ACT AGREEMENT (NASA/INDUSTRY)
  - FOUR IN PLACE
  - THREE IN NEGOTIATION
- BAILMENT AGREEMENT (NASA/INDUSTRY)
  - ONE IN PLACE
- MOA (INTRA AGENCY)
  - TWO IN PLACE
- "OUTREACH" (ACADEME & DOE)
  - FIVE ARCJET SYSTEMS PROVIDED
  - ION SYSTEMS IN FAB

LOW THRUST PROPULSION
" STRATEGIC " PROGRAM (1)



(1) ASSUMES PROPOSED NEP & DEEP SPACE PLATFORM PROPULSION FOCUSED PROGRAMS

LOW THRUST PROPULSION
" CURRENT " PROGRAM (1)



(1) ASSUMES PROPOSED NEP & DEEP SPACE PLATFORM PROPULSION FOCUSED PROGRAMS

LOW THRUST PROPULSION

"STRATEGIC" VERSUS "CURRENT" PROGRAM

LOW THRUST CHEMICAL

	PROGRAM	
TECHNOLOGIES	"CURRENT"	"STRATEGIC"
EARTH-STORABLE		
NTO/MMH	• VALIDATE 100LBF ROCKET FOR MMII	• VALIDATE 100LBF ROCKET FOR MMII • COMPLETE 15LBF ROCKET VALIDATION • APOGEE VERSION DEMO
NTO/N_2H_4	(1)	(1)
SPACE STORABLE LOX/N2H4 LOX/HC	• ROCKET DEMO	• ROCKET VALIDATION • VEHICLE APS ROCKET DEMO
INTEGRATED H/O		• RAD-COOLED ROCKET VALIDATION • VEHICLE APS PROGRAM INITIATED

"STRATEGIC" PROGRAM ENABLES AGGRESSIVE SPACE STORABLE AND INTEGRATED H/O LOW THRUST CHEMICAL PROGRAMS

(1) ASSUMED FOCUSED PROGRAM

LOW THRUST PROPULSION

"STRATEGIC" VERSUS "CURRENT" PROGRAM

LOW POWER ELECTRIC

TECHNOLOGIES	PROGRAM	
	"CURRENT"	"STRATEGIC"
ARCJET >600s, 1-2kW <1KW & 2-5KW	• ROCKET VALIDATION	• ROCKET, PPU, & GASSIFIER VALIDATION • SYSTEM TECHNOLOGY VALIDATIONS
DERATED" ION	• THRUSTER DEMO	• THRUSTER/PPU DEVELOPMENT
"HALL THRUSTER"	• TECHNOLOGY EVALUATION	• TECHNOLOGY EVALUATION

"STRATEGIC" PROGRAM ENABLES SECOND GENERATION ARCJET AND STATIONKEEPING ION OPTIONS

LOW THRUST PROPULSION

"STRATEGIC" VERSUS "CURRENT" PROGRAM

HIGH POWER ELECTRIC (1)

TECHNOLOGIES	PROGRAM	
	"CURRENT"	"STRATEGIC"
SEPS	• THRUSTER VALIDATION	• SYSTEM VALIDATIONS - THRUSTER - PPU - THERMAL & PROP. MGT. - INTERFACES • SYSTEM INTEGRATION INITIATED
NEPS (ROBOTIC)	• THRUSTER DEMO'S	• SYSTEM R&T INITIATED

"STRATEGIC" PROGRAM ENABLES SEP & ROBOTIC NEPS SYSTEM R&T

(1) MW CLASS NEPS FOCUSED PROGRAM ASSUMED

SPACECRAFT ON-BOARD PROPULSION (LERC, JPL)

- GOAL: PROVIDE DUAL-MODE (NTO/N_2H_4) PROPULSION FOR PLANETARY MISSIONS
- AUGMENTATION OBJECTIVE: [ASSURE DUAL MODE PROPULSION READINESS]
  - DEVELOP DUAL MODE HOT ROCKET
  - DEVELOP ADVANCED TANKAGE

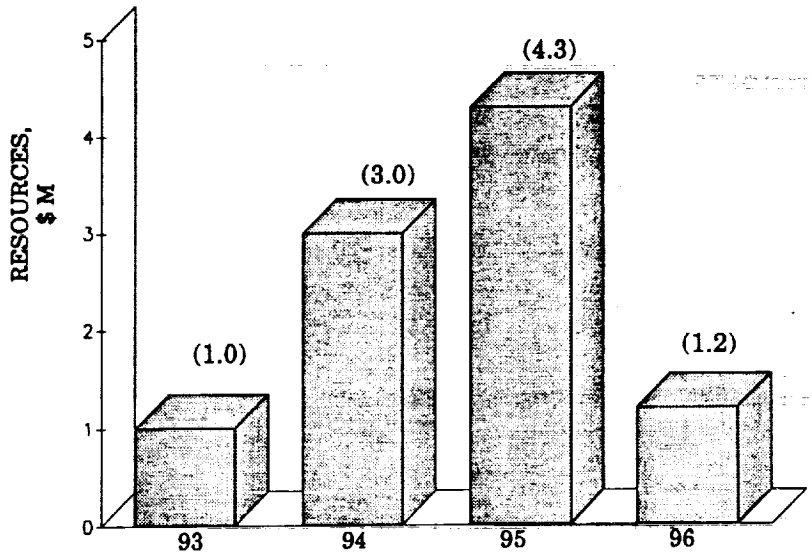
STATIONKEEPING PROPULSION (LERC, JSC)

- GOAL: PROVIDE INTEGRATED H/O & RESISTOJET SPACE STATION PROPULSION
- AUGMENTATION: [ENABLE LOGISTICS OPERATIONS BENEFITS FOR SPACE STATION]
  - DEVELOP H/O ROCKETS
  - DEVELOP LOW PRESSURE ELECTROLYSIS
  - DEVELOP SINGLE RESISTOJET FOR H_2O & WASTE GAS

AUXILIARY PROPULSION (JSC, LERC)

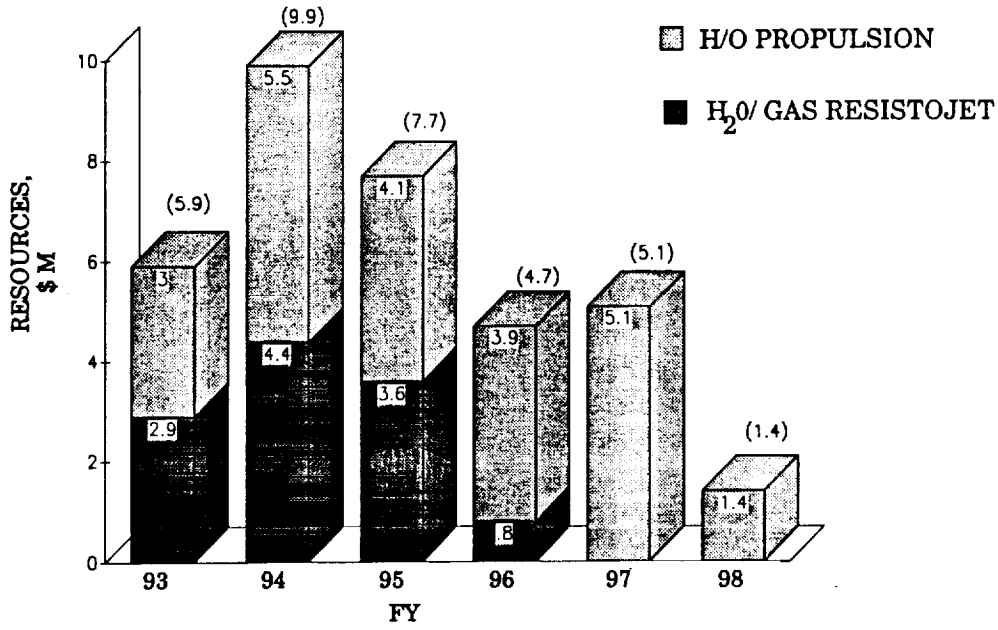
- GOAL: PROVIDE ADVANCED AUXILIARY PROPULSION FOR EARTH LAUNCH VEHICLES
- AUGMENTATION GOAL: [PROVIDE EVOLUTIONARY HI PERFORMANCE OPERATIONALLY EFFICIENT AUXILIARY VEHICLE PROPULSION]
  - PROVIDE RAD COOLED EARTH & SPACE STORABLE PROPULSION
  - PROVIDE INTEGRATED H/O PROPULSION

FOCUSED TECHNOLOGY
SPACECRAFT ON-BOARD PROPULSION
PLANETARY DUAL-MODE PROPULSION
"3X" PROJECT

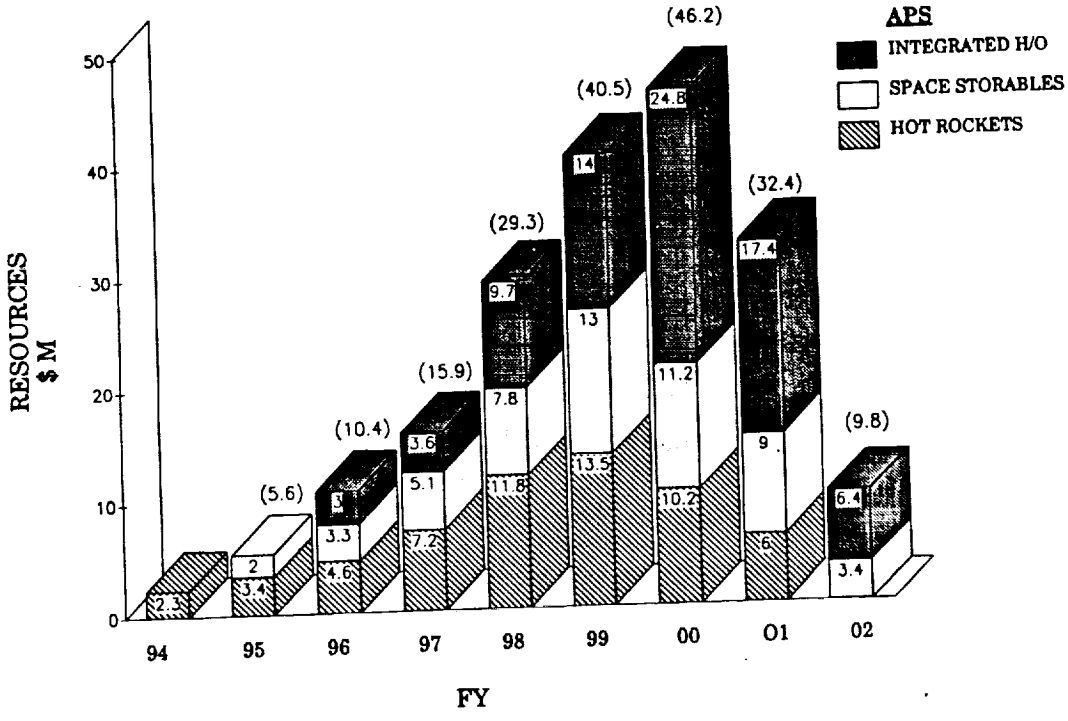


JOINT JPL/NASA LeRC PROJECT PROPOSED

FOCUSED TECHNOLOGY
SPACECRAFT ON-BOARD PROPULSION
SPACE STATION FREEDOM
"STRATEGIC"

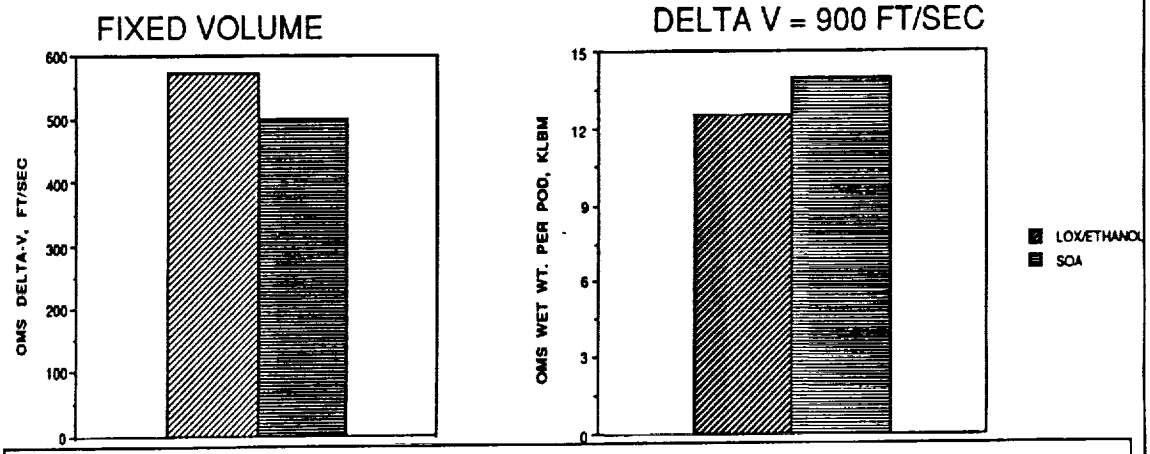


FOCUSED TECHNOLOGY
TRANSPORTATION
AUXILIARY PROPULSION
"STRATEGIC"



	Current Baseline	Potential Baseline
Propulsion Element Upmass	1 flight per year	1 flight per *5* years
Ground Processing (Man-Hours)	$200 K/Year	$200 K/ *5* Years
Dedicated SSF Hazardous Processing Facility	$50 Million	N/A

SPACE STORABLE IMPACT (1)

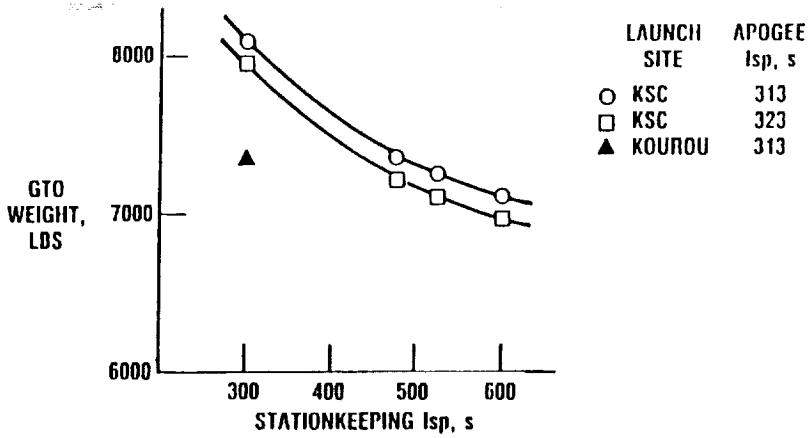


SPACE STORABLES

- OFFER SIGNIFICANT BENEFITS FOR FUTURE ETO VEHICLES

(1) REF: McDONNEL DOUGLAS STUDY FOR JSC (MDC E0713)

ON-BOARD PROPULSION IMPACTS(1)



ADVANCED STATIONKEEPING AND APOGEE PROPULSION

- **REDUCE GTO REQUIREMENTS**
- **MITIGATE LAUNCH SITE IMPACTS**

(1) 15 YEAR GEO LIFE, 3500 LBS EOL WEIGHT

CD 90 47467

ADVANCED ORBIT TRANSFER PROPULSION IMPACTS(1)

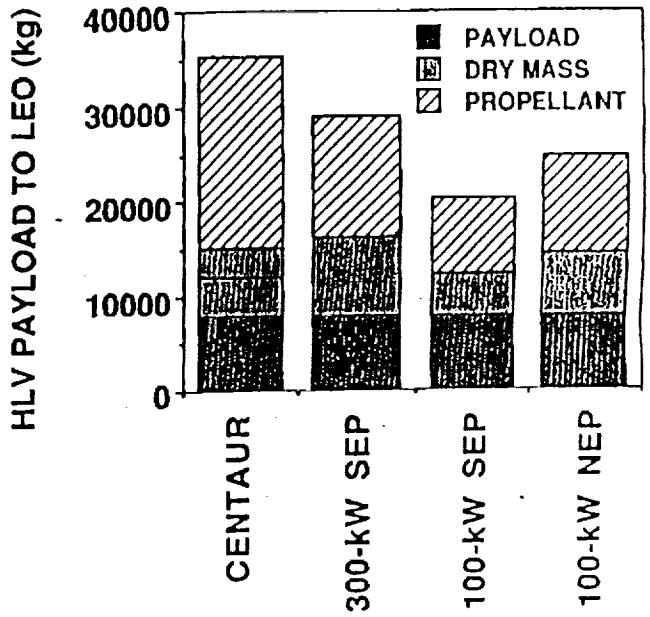
	ELECTRIC	CHEMICAL
		
MLEO, Lbs	10307	37782
TRIP TIME, DAYS	180	1
LAUNCHER	DELTA II	TITAN IV
OTV	SEPS	IUS

ELECTRIC PROPULSION OFFERS 3X MLEO REDUCTION

(1) AIAA 89-2496 "Electric Orbit Transfer Vehicle - A Military Perspective", S. Rosen and J. Sloan /AFSD. 5250 Lbs to GEO

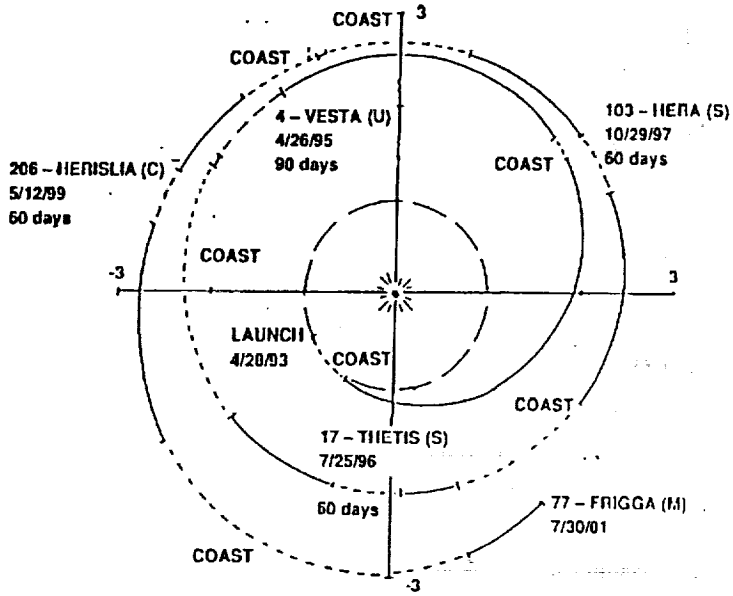
Significant Launch Mass Reductions Are Possible Using Electric Propulsion

- Electric Propulsion Reduces the LEO Launch Mass by 18 to 42 Percent
- A 300-kW SEP System Provides the Best Trip Time Performance
- Centaur Injection Is Replaced With Low-Thrust Escape



MBAR TRAJECTORY WITH SOLAR ELECTRIC PROPULSION ENABLES FIVE ASTEROID RENDEZVOUS PER MISSION

- FIVE ASTEROIDS CAN BE VISITED ON THE SAME MISSION WITH ELECTRIC PROPULSION; ONLY ONE ENABLED WITH NTO/MMH
- EXAMPLE ASTEROID TOUR INCLUDES:
  - 4 – VESTA (90 days)
  - 17 – THETIS (60 days)
  - 103 – HERA (60 days)
  - 206 – HERISLIA (60 days)
  - 77 – FRIGGA (TO EOM)



NEP MISSION VS BALLISTIC - KEY EXPECTED IMPROVEMENTS
FLIGHT TIME PAYLOAD MASS SCIENCE

1) NEPTUNE ORBITER/PROBE

- SHORTER FLIGHT TIME - 11 YRS VS > 18 YRS
- TRITON SCIENCE - ORBITER MISSION VS 41 FAST FLYBYS (4-5 KM/S)
- RING SCIENCE - POSSIBLE TO SPIRAL INWARD TO RING ZONE
- ATMOSPHERE SCIENCE - OBSERVATION FROM CLOSE (E.G. 3 R_N) ORBIT

2) PLUTO ORBITER/PROBE

- ORBITER MISSION VS FAST (13 KM/S) FLYBY FOR BALLISTIC MISSION
- SPIRAL INWARD AS LOW AS DESIRED
- RENDEZVOUS WITH CHARON
- DEPLOY NEPTUNE LANDER OR PROBE
- SHORTER FLIGHT TIME, 10.5 YEARS
- NEP IS ENABLING (BALLISTIC MODE TAKES > 36 YRS TO DO ORBITER)

3) JUPITER GRAND TOUR

- ORBITER MISSION FOR CALLISTO, GANYMEDE, EUROPA AND IO (IF RADIATION PROBLEM CAN BE TACKLED)
- DEPLOYMENT OF SOME LANDERS OR PENETRATORS

NEP MISSION VS BALLISTIC - KEY EXPECTED IMPROVEMENTS (CONTINUED)

3) MULTIPLE ASTEROID RENDEZVOUS

- MINIMUM OF SIX RENDEZVOUS WITH PREFERRED ASTEROIDS (SIZE, TYPE) VS ONE MAJOR TARGET PLUS ONE OR TWO SMALL TARGETS OF OPPORTUNITY
- ON AN AVERAGE OF ONE RENDEZVOUS EVERY TWO YEARS VS ~ ONE EVERY 4 YEARS

4) JUPITER POLAR ORBITER

- ADVANTAGE EXISTS IN LARGE PAYLOAD - POTENTIAL FOR MULTI-SPACECRAFT FIELDS AND PARTICLES EXPERIMENTS

5) COMET NUCLEUS SAMPLE RETURN

- BETTER PERFORMANCE AND ACCESSIBILITY TO LARGER NO. OF COMETS (MORE OPPORTUNITIES)
- PRESERVATION OF SAMPLE
- LOWER APPROACH SPEED WHEN RETURNING TO EARTH (V_∞=0 km/s)
- IF ALLOWED TO SPIRAL BACK INTO EARTH THEN ORBITAL SAMPLE RECOVERY INSTEAD OF HIGH VELOCITY (V_∞=15km/s) DIRECT ENTRY

LOW THRUST PROPULSION

- ESSENTIAL FOR SPACE MISSIONS
  - EARTH SPACE
  - PLANETARY
- PREDOMINANT LAUNCH & SPACE VEHICLE "PAYLOAD"
- HI LEVERAGE TECHNOLOGIES DEFINED
  - INITIAL TRANSFERS ACHIEVED
- BROAD & MAJOR BENEFITS ASSURED WITH SUPPORT:
  - SPACECRAFT
  - PLATFORMS
  - TRANSPORTATION